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HUMAN FACTORS ENGINEERING CONSIDERATIONS
IN DESIGNING NAVAL AIRCRAFT FOR MAINTAINABILITY

by

William Edward Baumgartner

June 1977

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HUMAN FACTORS ENGINEERING CONSIDERATIONS IN DESIGNING NAVAL AIRCRAFT FOR MAINTAINABILITY

by

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ABSTRACT

Rising maintenance costs and the necessity for increased availability have resulted in a new emphasis on maintainability as a design parameter in the acquisition of Naval air systems. Human factors engineering, traditionally considered a means of improving operator performance, is also a designer's tool for improving aircraft maintainability. Department of Defense directives mandating that all systems be designed according to specific human factors engineering and maintainability criteria confirm the necessity for including the human engineer in the designing of aircraft for maintainability. Appendix A, "The Checklist for Human Factors Engineering of Maintainability in Naval Air Systems Design," has been developed as a tool for aircraft designers and Navy design monitors to ensure human factoring criteria have been incorporated in the maintainability of the major aircraft subsystems.

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I. INTRODUCTION

A. BACKGROUND

Maintainability is a member of a family of system design characteristics which has come into vogue since World War II (Kline, 1976). Some of maintainability's better known and more developed siblings include reliability, availability, and survivability. Their common suffix "ability" is not accidental. It indicates their shared parentage in their mathematical derivations, probability. Military Standard 721B defines maintainability as:

> "A characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources."

Maintainability as an engineering discipline grew from the development of reliability in the late 1940's. Pioneering work in the field of maintainability during the latter 1950's was performed by psychologists and human factors engineers, rather than design engineers. Their efforts produced a set of design guides containing many practical applications in designing systems for maintainability which are still useful today (Kline, 1976).

During the 1960's and 1970's as the computer came of age, the emphasis in maintainability shifted from human factoring to the methods of quantification. Mathematical models were developed to use in the prediction and

demonstration of maintainability in design. At the same time, a profusion of military specifications were issued by the Materiel Commands of the military services in the areas of reliability and maintainability. Finally in the late 1960's the Department of Defense, in an effort to standardize the existing set of specifications, issued a set of military standards for maintainability (Kline, 1976). These standards will be discussed in Chapter III.

B. MAINTAINABILITY, AN ELEMENT OF AVAILABILITY

A more comprehensive definition of maintainability was proposed by Rigby, et al., (1961).

> "Maintainability is a quality of the combined features and characteristics of equipment design, job aids, and job supports which facilitate the rapidity, economy, ease, and accuracy with which maintenance operations can be performed, and the system thus kept in or returned to operating condition, by average... personnel, under the environmental conditions in which the system will be maintained."

Words such as rapidity and economy emphasize the motives behind the development of maintainability as a design characteristic - the desire to save time and/or cost in maintaining a system. Time has been the traditional criterion in measuring a system's maintainability characteristics, as well as its reliability traits.

Maintainability expressed as mean time to repair (MTTR) and reliability expressed as mean time between failures (MTBF) may be used to describe inherent system availability (Ai) by the following formula:

$$Ai = \frac{MTBF}{MTBF + MTTR}$$

As Crawford and Altman (1972) defined it, availability is the probability that a system will be operational at a given time. Therefore, the ultimate goal of the system designer is to properly balance maintainability and reliability characteristics through economic trade-offs, ensuring the desired system availability. Rigney (1970) observed that as long as systems are unreliable, maintenance will be the counterpart of operation. The two comprise the useful life of the system and therefore, ought to receive at least equal design effort when the system is engineered. Until the practice of dedicating an excessively disproportionate amount of the designer's resources and the procuring activity's funds to the operational objectives is ended, deficient systems will be produced.

C. MAINTAINABILITY AND THE MAINTENANCE TASKS

As stated previously maintainability involves those design characteristics that facilitate the maintenance of the system. The following is a list of nine maintenance tasks defined in MIL-STD-721B that comprise total system maintenance time:

TABLE I

List of the Maintenance Tasks

1. Servicing
2. Inspection
3. Preparation
4. Fault location
5. Item obtainment
6. Fault correction
7. Adjustment-Calibration
8. Checkout
9. Cleanup

Items 1 and 2 are preventive maintenance tasks. The remainder are incorporated in corrective maintenance of systems. In each of these nine tasks the human technician must be employed. It stands to reason then, if

maintainability is to be designed into a system, these maintenance tasks must be addressed in terms of human performance from the beginning of the design phase. An increase in maintainability implies a decrease in maintenance (repair time) which can only be accomplished by decreasing the time involved in some or all of the maintenance tasks. Since the human technician is a key element in each maintenance task, human factors engineering is an important design discipline that must be incorporated in the maintainability design.

D. HUMAN ENGINEERING AND MAINTAINABILITY

"Human factors engineering [also human factors or human engineering] can be considered the process of designing for human use" (McCormick, 1970). This definition implies that by human factors engineering, systems are to be designed to "fit" the operator, rather than the operator having to adapt to systems that were designed without regard to human capabilities.

Historically design engineers have considered man infinitely adaptable to the systems they design. During World War II, with the introduction of radar systems and new high performance aircraft, human capabilities and limitations as operators began to be recognized. This new awareness was the beginning of several fields in the behavioral sciences known variously as aviation psychology, engineering psychology, human engineering, and ergonomics (DeGreene, 1970). As stated previously, almost fifteen years passed before the psychologists and human engineers began applying their knowledge of human capabilities and limitations to designing systems for maintainability. "Maintainability has been like the uninvited relative to the

family dinner: no one wants to pay more than the minimum necessary attention to it, and everyone hopes it will go away at the earliest possible moment" (Rigney, 1970). McCormick in 1970 and Heimstra and Ellingstad as late as 1972 in stating the goals of human factors engineering failed to mention the maintainer; only the operator was considered. "Very few people really appreciate the magnitude of the maintenance workload entailed by the maintenance requirements for complex equipment" (Rigney, 1970).

In the previous section of this chapter, it was suggested that human factors engineering could reduce the time involved in each of the nine maintenance tasks. Kline in 1976 listed thirteen maintainability design factors which are applicable in this reduction of maintenance task time.

TABLE II

List of Maintainability Design Factors
(Kline, 1976)

1. Accessibility
2. Test Points
3. Controls
4. Labeling and Coding
5. Displays
6. Manuals, Checklists, Charts, Aids
7. Test Equipment
8. Tools
9. Connectors
10. Cases, Covers, Doors
11. Mounting and Fasteners
12. Handles and Handling
13. Safety

The list was compiled from over 20 maintainability guides and was ordered according to the number of publications in which each factor was presented. (Accessibility was mentioned 15 times, while safety's frequency was nine.) It indicates the extent to which the human engineer must be involved in the design for maintainability. Each of these design factors are elements of the purview of the human factors engineer.

As an example of the employment of these design factors in human engineering the nine maintenance tasks listed previously, consider the first task, servicing. Servicing of a system, often denoted preventive maintenance, includes such activities as fueling, lubricating, replacing filters or drive belts, changing tires, and the like. The design factors affecting servicing of systems consist of accessibility, labeling, displays, manuals, checklists, tools, covers, doors, mounting, fasteners, handles, handling, and safety. Depending upon the individual characteristics of different systems, this group of factors affecting the service task could increase or decrease. By employing the human engineer's special talents of applying human performance abilities in these design factors, all of the maintenance task times may be reduced.

II. MAINTAINABILITY IN THE DESIGN OF NAVAL AIRCRAFT

A. MAINTAINABILITY OF THE F-14A TOMCAT

Several reasons have been proposed in Chapter I for designing systems for increased maintainability. First, improved maintainability allows a reduction in the maintenance portion of life cycle costs for the system. Second, the accompanying increased availability enables the operation of the system for a greater percentage of its life. Third, the Department of Defense (DoD) has directed that the military services must ensure various Military Standards for maintainability are met when new systems are acquired. Finally, task induced stresses (unusual body positions, lifting of excessive weight, excessive information processing, etc.) on the maintainer may be reduced or eliminated if human factoring is included when designing for maintainability.

It is readily apparent that the driving forces behind DoD's promulgation of the maintainability standards were rapidly rising maintenance costs and the necessity to improve system availability. In the case of military aircraft, these two factors are especially evident. Chapanis wrote in 1965 that the U. S. Air Force found that due to increasing system complexity and automation, maintenance costs of new systems [aircraft] may amount to ten times their procurement costs. It is not unreasonable that such an estimate is true today for the U. S. Navy as well.

To give some perspective to such an estimate, consider the following example: The Navy is authorized to purchase 403 F-14A Tomcat aircraft at a "flyaway" cost of $14.1 million per airplane. If research and development costs, spare parts, and miscellaneous expenses are added, the unit cost rises to $20.4 million (Powers, 1976). The total "flyaway" price (1976 dollars) will be $5.7 billion (403 x $14.1 million). A conservative estimate of the lifetime maintenance expense would then be $57 billion in 1976 dollars.

One might argue that since the F-14A was developed after the issuance of the DoD Military Standards for maintainability, the Tomcat has achieved the required level of maintainability. Rear Admiral J. S. Christiansen, USN (retired), former Director of Plans and Programs and Assistant Deputy Chief of Naval Air Warfare, now with Grumman Aerospace Corporation, in 1976 implied that the F-14A was forced into production prematurely through a "phased-development" program to replace the aging F-4 when the Navy cancelled the F-111B for unsuitability. Subsequent funding restrictions and cutbacks by Congress and DoD have prevented the F-14 from progressing through the normal growth cycle (i.e., F-14A,B,C, etc.). thus, many state-of-the-art improvements in performance, reliability, and maintainability, which are already designed, have not been incorporated. Retired Vice Admiral Kent L. Lee, former commander of the Naval Air Systems Command, in an interview by <u>Aviation Week and Space Technology</u> magazine, stated that a big lesson learned with the F-14 program was not to rush into production. Future developmental programs will allow enough time to test for reliability and maintainability before full scale production (Robinson, 1977).

Admittedly, the F-14 was conceived under less than ideal conditions; however, ideal conditions as such may never

occur again, given the current atmosphere in defense spending. What the Tomcat does demonstrate is the need to include maintainability in the design of Navy aircraft from the initial conceptual stages of development. In order that the Navy's air arm be ready to fulfill its missions - projection of sea power ashore, air control of the sea lanes, and air defense of the fleet - aircraft availability must be ensured. Maintainability, as well as reliability, contributes to aircraft availability, and therefore, it deserves equal time in the design effort. In our current era of austere funding, it can no longer be assumed that new air systems will be able to proceed through a "normal growth cycle" to incorporate reliability and maintainability features omitted in the initial stages of development.

B. THE F-18 AND BEYOND

The current development of the Navy's F-18 and proposed development of vertical/short take-off and landing (V/STOL) aircraft are demonstrating a refreshing change in aircraft procurement policy. Included in the Naval Air Systems Command's management approach to these projects is the requirement to begin in the conceptual design phase with inherent system maintainability and reliability characteristics (Robinson, 1976). In order to encourage contractor efforts in designing maintainability and reliability into the F-18, an Award Payment Plan is included in the full-scale development contract. In addition to specific minimum performance requirements, at certain points in the full-scale development test program, specified reliability and maintainability factors are to be evaluated. The contractor may earn potential award payments of $12 million in each case, for the achievement of reliability and maintainability performance goals in excess of the minimum

requirements (Bulban, 1976 and Maintainability Project Management Plan for the F-18 [proposed], 1976).

These contract incentives are a reflection of a new management philosophy within the Naval Air Systems Command. The popular byword associated with this philosophy is "Big R and little m," meaning the procurement of systems with sufficient reliability characteristics and low maintenance requirements. This does not suggest that maintainability is to be sacrificed in order to improve reliability. It is true that increased reliability can reduce the number of maintenance actions required for an air weapon system by extending the time between system failures (MTBF). However, in order to reduce the maintenance time (MTTR) associated with each failure, maintainability must be increased (refer to the definition of maintainability in Chapter I).

The typical measures of maintainability for aircraft systems are based on maintenance manhours per flight hour (MMH/FH) rather than mean time to repair. MMH/FH usually refers only to unscheduled maintenance actions. A more comprehensive measure which includes scheduled maintenance is direct maintenance manhours per flight hour (DMMH/FH). A reduction of either ratio indicates increased maintainability.

The parameter maintenance manhours lends itself more readily to the discussion of the reduction of maintenance task time through human factors engineering. Reducing the number of manhours required for individual maintenance actions can allow the reduction of the maintenance force for a Navy-wide system of the magnitude of the F-14 or F-18. A Brookings Institution study in 1975 estimated the total military compensation of a typical E-5 technician at nearly $15,000 for that year (Binkin, 1975). An aircraft that required 1000 fewer maintainers could save $15 million per

year or almost one third of one billion dollars in 1975 salaries over a 20 year life.

C. PURPOSE OF THIS THESIS

It has been established that the Naval Air Systems Command is pursuing a procurement policy to ensure future Naval aircraft will be designed for maintainability and that human factors engineering techniques must be included in this design process. While on temporary additional duty at the Naval Air Development Center during the spring of 1976, the author was involved with the Center's Human Factors Engineering Division of the Crew Systems Department in developing a plan for monitoring the human factoring efforts in the F-18 maintainability design for the Human Factors Advisor at Naval Air Systems Command. This thesis has grown out of that experience. Its purpose is to provide one tool for maintainability design review groups and system designers to assure appropriate human engineering techniques are incorporated in the maintainability design of Naval aircraft.

Chapter III will present an overview of pertinent military standards and specifications for maintainability and human factors engineering. Special attention will be attributed to those areas of the maintainability standards directly affected by human engineering. The fourth chapter will be concerned with the development of "The Checklist for Human Factors Engineering of Maintainability in Naval Air Systems Design" [Appendix A].

D. THE NAVAL AIR MAINTENANCE ENVIRONMENT

Operation of Naval aircraft from aircraft carriers, destroyers, and frigates at sea and from coastal Naval Air Stations presents unique maintenance as well as operational design considerations. The detrimental effect of the ocean environment on aircraft integrity and reliability, e. g. salt air corrosion, has been a continuing problem for the air wings of the Navy. These external conditions also impinge on system maintainability factors as well. Operating aircraft at sea mandates maintaining those aircraft at sea. Therefore, in order to completely understand the peculiar problems of maintaining Naval aircraft, one must understand the peculiarities of the environment in which that maintenance is performed.

The first problem involves the degree of logistic support, especially supply, special equipment and personnel, and work areas that are available aboard ship. Even aircraft carriers of the size of Enterprise or Nimitz have limitations not encountered at land bases. While it is true that some Naval aircraft are strictly shore-based, most operate primarily from aircraft carriers and must be maintained aboard those aircraft carriers, especially in wartime situations. Supply facilities on board are limited by the size of the ship's spaces, and supply lines may be non-existent at sea. On board spare parts then become a reliability as well as maintainability problem. (Note: supply is beyond the scope of this thesis and will not be addressed specifically.) In the same manner special equipment and personnel are restricted by the ship's size and operations. Elaborate or unique test equipment to support a specific aircraft may require precious work area.

Contractor (factory) representatives in sufficient numbers may not be authorized to sail with the air wing.

These logistical restrictions provide fertile areas for the human engineer to offer solutions in the early design stages of the aircraft. For example, the amount of supply support available will determine the level at which the replacement (with a new part) versus repair (of the failed part) trade-off is instituted in the maintenance design. Restrictions on special equipment and personnel mandate designing aircraft to be maintained by "average" personnel using common tools and equipment. limited hangar deck workspace and flight operations often require that aircraft maintenance be performed on the flight deck, thereby separating the aircraft from the already limited maintenance support. Physical separation from available shipboard logistic support adds the burden of carrying tools and replacement items long distances through less than ideal conditions.

Flight deck maintenance presents the second set of problems encountered in designing Naval aircraft for maintainability - weather and sea conditions. Exposure to the ocean environment is not only detrimental to aircraft material integrity but also can be detrimental to the technician's performance. Extreme temperature, humidity, precipitation, sea spray, wind, and pitching and rolling decks all contribute to the maintainer's discomfort and distraction, possibly resulting in maintenance errors. Additional stresses will be encountered by the maintenance man during flight operations. Engine noise, jet blast, and propeller wash experienced at the close ranges of a carrier flight deck, in addition to posing safety and health hazards, are especially annoying even during the briefest exposures. These environmental problems are magnified when maintaining the light airborne multi-purpose system (LAMPS)

helicopters or future V/STOL aircraft on board the smaller U. S. Navy destroyers and frigates.

III. MILITARY STANDARDS AND SPECIFICATIONS

In 1974 Casey and Sturm observed that the requirements for implementing human factors engineering in the Navy's systems acquisition process were adequate but that the philosophy and enforcement of the human engineering norms were weak. As discussed in Chapter II, that philosophy is changing within the Naval Air Systems Command; however, it remains to be seen if proper enforcement of the human engineering directives is accomplished, especially in the area of maintainability.

There are four pertinent DoD directives for maintainability and human factors engineering:

1. Military Standard 470 (MIL-STD-470), _Maintainability Program Requirements (For Systems and Equipments)_.

2. Military Standard 471A (MIL-STD-471A), _Maintainability Verification / Demonstration / Evaluation_.

3. Military Standard 1472B (MIL-STD-1472B), _Human Engineering Design Criteria for Military Systems, Equipment and Facilities_.

4. Military Specification 46855A (MIL-H-46855A), _Human Engineering Requirements for Military Systems, Equipment and Facilities_.

It is essential that the points at which these directives interact during the design phase of the procurement process be recognized in order to optimize the ultimate

maintainability attributes of systems, in this case Naval aircraft. This chapter will be devoted to summarizing these directives and indicating the points of interaction.

A. MIL-STD-1472B

As its title implies, MIL-STD-1472B institutes general design and development criteria for procuring Military systems and equipment. It is intended to present human engineering principles and practices in establishing these design criteria. Among the stated purposes of the standard are achievement of required operator and maintainer performance, minimization of skill and personnel requirements and training efforts, achievement of required personnel-equipment reliability, and fostering standardization of systems. The standard includes a compilation of anthropometric data from several military sources, an extensive collection of control/display design criteria, hazard and safety considerations, and requirements for certain specialized systems or equipment such as ground vehicles, remote handling devices, and air crew stations.

The chapter of MIL-STD-1472B named "Design for Maintainability" is, of course, of most importance for the theme of this thesis. It institutes human engineering design criteria applicable for all military systems and as such, can be considered a starting point from which maintainability design criteria for Naval aircraft may be developed. The subparagraphs of this chapter form an outline of the human factors engineering principles to be incorporated in the maintainability design, as follows:

1. General. General human engineering criteria to be satisfied in the system maintainability design involve

areas such as: standardization, grouping of functions, separate adjustability, removal/replacement/repair, modular replacement, assembly/disassembly, foolproof design, special tools, and clothing constraints.

2. Mounting of Components within Units. Components are to be arrayed within units of equipment or systems to facilitate maintenance on the individual units.

3. Adjustment Controls. Calibrating or adjusting control devices must incorporate the design criteria presented in the chapters dealing with controls and displays.

4. Accessibility. Access to components may not be hindered by system structural members, other more difficult to remove components, less critical system components, or low-failure-rate items. Access includes visual as well as physical access to check points, calibration points, test points, cables, connectors, and labels.

5. Lubrication. Lubrication points must be accessible without disassembly of the unit and must be properly labeled.

6. Unit Cases and Covers. Cases and covers are required to be designed for ease of alignment, removal and closure.

7. Access Openings and Covers. Areas of frequent maintenance must have quick access openings to include completely removable or self-supporting covers and proper labeling.

8. Physical Access. Access openings must be sufficiently large to permit the performance of the required

maintenance task. Openings must allow hand and arm or whole body access, as necessary for the task to be performed. Visual only access openings must be covered with the minimum necessary cover consistent with the operational environment and stresses, i.e., no cover, transparent window, break-resistant glass, or quick-opening cover of opaque structural material.

9. Fasteners. The number and type of fasteners used to secure covers, cases, etc. shall be comensurate with operational necessity. Hand operated or standard tool operated, quick-release, captive fasteners, readily accessible and common throughout the system should be provided.

10. Unit Design for Efficient Handling. Units shall be designed for quick removal of irregular or fragile extensions. Appropriate handles or grasps must be included with removable units. Maximum weights to be lifted, height of lift, and push/pull forces required in handling units are tabled in the chapter.

11. Mounting. Units shall be designed so that they cannot be mounted improperly. Mounting considerations to facilitate removal or access are use of common tools, straight-line removal, alignment pins, coding (i.e., keying), rollout racks, limit stops, interlocks, braces, rear access, and minimization of covers or panels.

12. Conductors. Conductors must be properly bound into cables, coded, clamped or ducted, and of sufficient length to provide ease of unit check-out. Additional requirements include: cable accessibility, shielding/protection from wear or fatigue, and functional labeling.

13. Connectors. Electrical connectors and plugs shall incorporate design characteristics to facilitate removal and replacement, such as: quick disconnection, keying/aligning pins, labeling/coding, simplicity, accessibility, etc.

14. Test Points. Test points shall be located close to the corresponding displays and controls, labled, and provided in sufficient numbers to obviate the necessity for removing subassemblies to accomplish trouble-shooting.

15. Test Equipment. Portable test equipment must be designed for self-containment of electrical leads, probes, spares, manuals, and special tools required for operation. Operating instructions shall be affixed to the equipment.

16. Fuses and Circuit Breakers. When required by the system, indication of fuse or circuit breaker opening must be provided. Fuse/circuit breaker panels shall indicate each fuse's rating and the equipment served by individual breakers or fuses. Fuses shall be readily accessible, spares readily available, and no special tools shall be required for fuse replacement unless required by safety considerations.

17. Gas and Fluid Line Identification. Lines and conduits that direct gases, fluids or electrical wiring shall be identified and labled as directed in MIL-STD-1247.

Adherence to the provisions of this chapter will surely enhance the inherent maintainability of systems, especially those systems that are extensively electrical or electronic in nature. Herein lies the shortcoming of this chapter on

design for maintainability. Items 12 through 16 above apply specifically to electrical/electronic systems. While the remaining twelve points are more general, the overall impact of "Design for Maintainability" is in the engineering of electrical or electronic systems. It is true that electrical distribution and electronics are extensively employed in modern Naval aircraft; nevertheless, there are many other aircraft subsystems which must be addressed in the complete design for maintainability. The principles of "Design for Maintainability" must also be applied to the aircraft's fuel, hydraulic, power plant, weapons, life support, and airframe subsystems.

B. MIL-H-46855A

MIL-H-46855A establishes and defines the overall requirements for applying the human engineering principles and criteria presented in MIL-STD-1472B during the procurement of military systems, thereby effectively integrating man into the system. The specification requires the prospective contractor to state his approach in his Human Engineering Program Plan which is submitted in response to the Request for Proposal (RFP). The Human Engineering Program Plan, upon acceptance of the proposal, becomes part of the procurement contract.

The three major areas of the system acquisition process where these human factors engineering principles are to be employed are analysis, design and development, and test and evaluation. The objectives of analysis are identification and definition of system operations, maintenance, training, and control functions; allocation of these functions to man and/or machine; analysis of the tasks comprising these functions; and development of system specific human

engineering design criteria and operation and maintenance procedures. The human engineering inputs developed in the analysis phase and comensurate with MIL-STD-1472B are to be incorporated into the detailed design. These human engineering provisions shall be evaluated during the design reviews to ensure their adequacy. The purpose of the test and evaluation phase is assurance of the fulfillment of MIL-H-46855A and contract requirements, demonstration of conformance to MIL-STD-1472B, quantification of man-machine system performance, and indication of the introduction of possible undesirable design or procedural features.

MIL-STD-1472B and MIL-H-46855A are a complementary pair of directives that mandate the implementation of human factors engineering principles in the development and acquisition of military systems, equipment and facilities. The former establishes the criteria by which the systems are to be human engineered, and the latter establishes the requirements for applying those criteria. Both documents specifically address maintenance and maintainability as integral parts of the human engineering of the total system.

C. MIL-STD-470

MIL-STD-470, _Maintainability Program Requirements (For Systems and Equipments)_, is the maintainability equivalent of human factors engineering's MIL-H-46855A. The overall requirement of the standard is that the _contractor_ shall establish and maintain an effective maintainability program that is integrated with the system/equipment design engineering program to assure effective, timely, and economical accomplishment, consistent with the system/equipment type and complexity. Specific tasks that must be incorporated into the maintainability program

include preparation of the maintainability program plan, maintainability prediction and analysis, establishment of maintainability design criteria, performance of design tradeoffs, preparation of inputs to the detailed maintenance plan, collection of data, submission of status reports, participation in design reviews, and demonstration of maintainability requirements.

The requirement to establish maintainability design criteria can be facilitated by adherence to MIL-STD-1472B and MIL-H-46855A. The following, a set of design guidelines from MIL-STD-470, which should be considered for incorporation into the maintainability design bears a striking similarity to MIL-STD-1472B's "Design for Maintainability."

1. <u>Reduce the complexity of maintenance by</u>: provision of adequate accessibility; provision for interchangeability of like components; utilization of Mil-Standard parts; limitation of the number and variety of tools, accessories and support equipment; and assurance of compatibility among system equipment and facilities.

2. <u>Reduce the need for and frequency of design-dictated maintenance activities by using</u>: fail-safe features, components which require a minimum amount of preventive maintenance, tolerances which allow for wear, and adequate corrosion prevention/control features.

3. <u>Reduce maintenance downtime by designing for rapid, positive and complete</u>: fault detection, preparation for maintenance, fault location, fault correction, adjustment and calibration, and checkout.

4. <u>Reduce design-dictated maintenance support costs by limiting</u>: the need for special tools, support

equipment, and facilities; the requirements for depot or factory maintenance, consistent with system cost/effectiveness; and the need for extensive technical information.

5. Limit maintenance personnel requirements by applying human engineering principles such as: identification and accessibility of parts, test points, calibration controls, and connectors; ease of handling, mobility, transportability, and storeability; logical sequencing of maintenance tasks; and implementation of relevant personnel physiological parameters.

6. Reduce the potential for maintenance error by designing to eliminate: the possibility of incorrect connection, assembly, and installation; dirty, awkward, and tedious job elements; and ambiguity in labeling, coding, and technical publications and information.

It is readily apparent that almost every maintainability point above is addressed by the human factors engineering criteria contained in MIL-STD-1472B. It is difficult to find a more convincing argument for including the human engineer in the maintainability design process. MIL-STD-470 mandates human factors engineering considerations in establishing its maintainability design guidelines.

D. MIL-STD-471A

Military Standard 471A, Maintainability Verification / Demonstration / Evaluation, provides procedures and test methods for measurement of the qualitative and quantitative maintainability requirements prescribed by MIL-STD-470. In addition it provides for qualitative assessment of various

integrated logistic support factors associated with or having a direct influence upon the achievement of maintainability parameters and item downtime, e. g., personnel, tools, test equipment, technical publications, maintenance concepts, and supply. Assessment shall be performed in accordance with the contractor's proposed maintainability test plan, an element of his maintainability program. This testing is to be carried out in three stages: verification, demonstration, and evaluation. Verification (Phase I) is the contractor's effort, monitored by the procuring activity, to determine the accuracy of the maintainability engineering analysis, to update analytical data, to identify maintainability design deficiencies, and to gain progressive assurance that the maintainability of the item can be demonstrated in subsequent phases. Demonstration (Phase II) is the joint effort of the contractor and procuring activity to determine whether satisfactory achievement of specific maintainability contractual requirements has occurred. Evaluation (Phase III) is the procuring activity's effort to determine the impact of the operational, maintenance, and support environment on the item's maintainability parameters at all levels of maintenance and to demonstrate the depot level maintenance tasks (MIL-STD-471A).

The standard delineates the procedures and responsibilities for each test phase. Rules for data collection, parameter calculation and report submission are included. Appendix A to MIL-STD-471A outlines a method for selecting a sample of corrective maintenance tasks to be used for demonstration of the repairs of simulated failures.

Appendix B of MIL-STD-471A presents eight methods for demonstrating system or item maintainability. Both parametric and nonparametric techniques are provided. The parametric methods are based on the assumption that

maintenance time is distributed log-normally, i. e. maintenance time is a positive random variable, the natural logarithm of which is distributed normally:

$$f(X) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(1/2)\{(\ln X - \theta)/\sigma\}^2}$$

where:

X = the random variable maintenance time

θ = the mean of ln X

σ^2 = the variance of ln X

The assumption of log-normality has been shown to be valid by Kline (1976) for the maintenance time of certain items, e. g., electronic units. The attributes that may be tested by these methods are central tendency (mean or median), critical percentiles, critical time or manhours, and manhour rates.

MIL-STD-470 and MIL-STD-471A provide the requirements for including maintainability into the systems acquisition process and for proving that the requisite maintainability is being achieved. As was shown earlier, MIL-STD-470's maintainability design criteria are covered to a great extent by MIL-STD-1472B. One purpose of the verification phase of MIL-STD-471A is identification of maintainability design deficiencies.

IV. THE MAINTAINABILITY DESIGN CHECKLIST

A. THE CHECKLIST APPROACH

The concept of employing checklists or questionnaires as design guides is not novel. Topmiller (1964) surveyed a sample of 90 U. S. Air Force maintenance personnel with a maintainability human engineering questionnaire. His study was based on the statistical analysis of the technicians' responses to 114 maintainability design questions as they pertained to the system on which each maintainer worked. The systems examined were the B-52 bomber, KC-135 tanker aircraft and the GAM-77 missile system, all existing in the operational inventory of the USAF. The 114 questions were grouped into seven human engineering catagories called prediction factors [Table III]. The goal of the study then was the identification of those areas where human engineering affects air system maintainability.

TABLE III

Maintainability Prediction Factors
(Topmiller, 1964)

1. Maintenance Safety
2. Maintenance Information Displays
3. Fasteners and Tools
4. Alignment and Keying
5. Manual Control Layout
6. Workspace Configuration
7. Accessibility

The factors found to be most highly related to systems maintainability were manual control layout, alignment and keying, and maintenance information display systems (Topmiller, 1964). It was intended that the results of

Topmiller's research would demonstrate those areas of existing air systems where human factors engineering criteria affect maintainability and thus provide a basis for future design criteria.

Two U. S. Army publications, Human Factors Engineering Design for Army Materiel (MIL-HDBK-759) and Engineering Design Handbook: Maintainability Guide for Design (AMCP 706-134), present maintainability/human factors engineering checklists for designers of Army systems. The former like MIL-STD-1472B is heavily oriented in electronics and electrical subsystem maintainability. The latter takes a more balanced approach by addressing mechanical, hydraulic and other subsystems and by including a chapter on aircraft (however, the checklist approach was not applied to aircraft).

The Naval Ordinance Systems Command's Maintainability Engineering Handbook (NAVORD OD 39223) contains a chapter entitled "Equipment Design Guidelines" which employs the checklist format. Although this is a NAVORD publication, much of its contents are applicable for Naval air systems also. The Boeing Aerospace Company has prepared an Analyst's Guide for the Analysis Sections of MIL-H-46855A for the Naval Air Development Center. Among the 22 human factors engineering analysis techniques presented is the "MIL-STD-1472B Checklist," which is described as a design verification technique "used to ensure proper application of human engineering design criteria to equipment drawings, mockups, and hardware" (Geer, 1976). Essentially this checklist method involves removing applicable pages from MIL-STD-1472B and adding space to the right of each subparagraph for noting compliance to the criteria and making comments.

"The Checklist for Human Factors Engineering of Maintainability in Naval Air Systems Design" [Appendix A] is

a compilation of the preceding checklists and MIL-STD-1472B criteria and is intended as a tool to be used by aircraft design engineers and Navy design monitoring personnel to ensure that proper human engineering criteria are being incorporated in the aircraft's maintainability design. The checklist is subdivided into sections dealing with the basic aircraft subsystems: airframe, hydraulics, power plants, electrical/electronics, weapons, fuel, and crew systems. Special attention is devoted to problems encountered where two or more subsystems interface. Servicing and ground support equipment (GSE) interfacing is also covered.

B. THE SUBSYSTEMS

The subsystems approach to developing "The Checklist for Human Factors Engineering of Maintainability in Naval Air Systems Design" permits editing of MIL-STD-1472B maintainability criteria and including only those items germane to specific functional subsystems. In that way the designer or design monitor of a component of the hydraulics subsystem, for example, would not have to unnecessarily review criteria that pertain solely to the electronics or other subsystem. On the other hand, it is recognized that many of these design principles (e. g., accessibility, adjustment controls, etc.) are applicable to all or most of the subsystems. Therefore, the first section of the checklist, labled "General," will present those criteria relevant to all subsystems, with the remaining sections listing those criteria pertinent to the specific functional areas.

In order to lay a ground work for the functional checklists, the remainder of this chapter will be devoted to briefly describing each of the aircraft subsystems. These

descriptions will necessarily be broad in scope so as to be applicable to all Naval aircraft - fixed-wing or helicopter, large or small, jet or propeller powered. In addition, areas where two or more subsystems interface and human factors engineering deficiencies may result are discussed.

1. Airframe

The airframe can be considered that part of an aircraft that distinguishes it from any other system. It includes the aircraft's skin and the structural framework that supports the skin and all of the other subsystems. The major components of this subsystem include the airfoils (wings, fuselage, and empenage), control surfaces (ailerons, rudders, elevators, flaps, and trim tabs), landing gear, canopies and wind screens, and interior decks and bulkheads. Because the airframe contains and supports all of the other subsystems, it has a great influence on the human factors engineering of those subsystems' maintainability. Airframe aerodynamic and structural requirements may limit the application of the human engineering accessibility, equipment mounting, access openings and covers, and test point criteria. In such cases, design trade-offs or major redesigning of the system must be performed in order to ensure that human factoring of maintainability is accomplished.

2. Electrical/Electronics

The aircraft electronics subsystem is often referred to as the "black boxes," i. e. radios, navigation equipment, radar, computers, television, electronic warfare equipment, and the associated wiring and antennae. The electrical power distribution system includes the batteries,

generators, auxiliary power units (APU), circuit protection devices, wiring, and electrical display instruments. Because of their similarities, these two subsystems will be considered as a unit. As in the case of the airframe, the electrical subsystem has a direct bearing on many of the other functional areas. Certain engine starters, fuel and hydraulic pumps, and electrical display instruments for monitoring other subsystems receive their power through the electrical power distribution circuits. The points at which these functional overlaps occur deserve special attention from the maintainability engineer.

3. Power Plants

The power plants subsystem is that part of the aircraft that produces the propulsive energy for the system. Engines, propellers, helicopter rotors, clutches, and transmissions are the major components of the propulsion subsystem. The engines interface with other subsystems by providing the mechanical energy to drive generators, pumps, and certain other auxiliary equipment.

4. Hydraulics and Fuel

The hydraulics subsystem provides the motive power to the control surfaces and other moving components of the airframe. This is accomplished by pumps, fluid lines, valves, tanks, and actuators. The devices actuated by this subsystem include: brakes, landing gear, control surfaces, speed brakes, and wing folding actuators. The interfaces between this subsystem and the airframe, electrical and power plants subsystems have already been noted. The requirement that carrier-based aircraft have folding wings (and often folding vertical tails) for conservation of deck

space can cause accessibility problems to weapons subsystem components outboard of the folds and for certain fuselage areas beneath the folded wings. Normally wings are folded onboard the ship just after arrestment (landing) and remain so until just before the catapult launching.

The fuel and other liquid handling subsystems are similar to the hydraulics subsystem except they do not have actuators. The purpose of the fuel subsystem is delivery of fuel to the engine. Fuel tanks, integrally mounted within the wings, can cause extreme accessibility problems if human factors engineering criteria are not adhered to.

5. Weapons

The weapons subsystem includes those integrally mounted devices of the aircraft upon which ordinance stores are mounted, such as: cannon, missile rails, wing stations, pylons, and bomb racks. Elements of the hydraulic and electrical/electronics subsystems provide controls and power for these devices.

6. Crew Subsystem

The crew subsystem consists of cockpits, crew stations, emergency egress devices, and life support equipment (oxygen, pressurization, and temperature control). The cockpit and crew stations interface with all other subsystems through the controls and displays located therein. It was noted earlier that human factors engineering of operator stations has preceded and possibly exceeded human engineering of maintainability; however, that does not imply that a well-engineered crew station from the operator's point of view is also well-engineered for the

maintainer. The operator is primarily concerned with the exterior of his consoles and panels - what he can see and grasp. The maintainer must also have access to what lies behind the consoles.

C. SAFETY

"Maintainability features are also safety features" (AMCP 706-134). Maintenance safety has been mentioned often throughout this thesis. However, it may have been noted that up until this point safety has not been discussed as a separate design item. The intent is to create an awareness for applying safety principles throughout the entire maintainability design process rather than treating it as an extra design problem. For these reasons maintenance safety criteria will be incorporated in each section of the checklist as integral parts of the subsystems' maintainability design.

V. CONCLUSION

A. SUMMARY

With the increasing complexity of each generation of Naval aircraft and the accompanying rising maintenance costs, it has become imperative that beginning with the F-18, all new aircraft procurement programs include maintainability in systems designs. The application of human factors engineering techniques in this design process can contribute significantly to achieving the desired level of maintainability by indicating ways of reducing maintenance task time, required technician training and skill levels, and logistic support. The result of these reductions is increased aircraft availability and decreased maintenance costs.

Department of Defense human factors engineering and maintainability directives (MIL-STD-1472B, MIL-H-46855A, MIL-STD-470, and MIL-STD-471A) have established criteria and program requirements for implementation in the acquisition of military systems. Careful examination of these documents has revealed the complementary role of human engineering in designing for aircraft maintainability. Such a revelation should not be surprising to the designer who understands the extent to which the human technician is involved in maintaining Naval aircraft. Therefore, until aircraft are completely reliable or are capable of maintaining themselves, one requirement of design engineers is to ensure that the proper human factors engineering criteria have been

incorporated in the aircraft in order to facilitate their maintenance by human beings. To aid these engineers and their Navy counterparts, the design monitoring teams, in fulfilling this requirement, Appendix A of this thesis, "The Checklist for Human Factors Engineering of Maintainability in Naval Air Systems Design," has been developed. This checklist, derived from MIL-STD-1472B and several Army and Navy design guides (AMCP 706-134, MIL-HDBK 759, and NAVORD OD 39223), is oriented for application in the design of the major aircraft subsystems: airframe, electrical/electronics, power plants, hydraulics and fuel, weapons, and crew subsystems. It is intended to indicate possible human factors deficiencies during the early stages of development, while corrections can be more easily made.

B. RECOMMENDATIONS

The soon to be published Human Factors Test and Evaluation Manual by the Pacific Missile Test Center is a detailed set of procedures for demonstrating the accomplishment of human factors engineering objectives in systems development, including human factors engineering in maintainability. Although this guide pertains to systems in general and is not specifically adapted for air systems, it represents the most up-to-date human engineering research in the Navy. As such, after its publication it should be used to update "The Checklist." Similarly, state-of-the-art aircraft hardware technology changes should be incorporated as needed in the checklist.

An expansion of the checklist into a survey questionnaire similar to Topmiller's (1964), that can be administered to maintenance personnel, would serve as a means for developing a data base for the statistical analysis of the effect of

human factors engineering on maintainability from the maintainer's point of view. Such an analysis would be an invaluable indicator of those areas where the human engineer can reduce the workload requirements for maintaining the Navy's air fleet.

APPENDIX A

THE CHECKLIST FOR HUMAN FACTORS ENGINEERING OF MAINTAINABILITY IN NAVAL AIR SYSTEMS DESIGN

INSTRUCTIONS

The following checklist is intended to be used by aircraft design engineers and Navy design monitoring personnel to ensure that human factors engineering principles have been adequately incorporated into the aircraft's design for maintainability. The checklist is divided into seven sections, the first of which is entitled "General" and is pertinent to most or all aircraft subsystems. The remaining six pertain to the six functional subsystems: airframe, electrical/electronic, power plants, hydraulics and fuel, weapons, and crew subsystems.

Proper employment of the checklist requires that the user answer each applicable item in the "General" section and in any subsystem section appropriate to the equipment under consideration. The questions are worded so that an affirmative response indicates proper compliance with the subject human factors engineering criterion. In such cases the word "YES" is to be circled. Failure to comply with the criterion requires circling "NO" and justification under "COMMENTS." If the question is not applicable, "N/A" is to be circled and an explanatory statement is to be made after "COMMENTS." Numbers within parentheses after some items are references to the relevant subparagraphs in MIL-STD-1472B.

A. GENERAL

1. Are standard parts used to the maximum extent feasible (5.9.1.1)?

YES NO N/A

COMMENTS

2. Is the equipment designed for rapid easy removal and replacement of modularized subassemblies (5.9.1.3)?

YES NO N/A

COMMENTS

3. Are subsystem components grouped by function (5.9.1.4)?

YES NO N/A

COMMENTS

4. Is each functional unit separately adjustable (5.9.1.5)?

YES NO N/A

COMMENTS

5. Is fault detection and isolation facilitated by the design of the equipment (5.9.1.6)?

YES NO N/A

COMMENTS

6. Does the removal, repair, and replacement of defective units require only one individual (5.9.1.8)?

YES NO N/A

COMMENTS

7. Can the equipment be maintained by personnel wearing special protective clothing, i. e. arctic or foul weather gear (5.9.1.9)?

YES NO N/A

COMMENTS

8. Is the equipment designed so that it cannot be improperly installed or mounted (5.9.1.10)?

YES NO N/A

COMMENTS

9. Can the equipment be maintained by personnel who have not had special training?

YES NO N/A

COMMENTS

10. Can all instructions and technical manuals be understood by individuals with a high school education or less?

YES NO N/A

COMMENTS

11. Can the maintenance tasks be performed with common tools, i. e. no special purpose tools?

YES NO N/A

COMMENTS

12. If ground support equipment (GSE) is necessary for maintenance, can standard, in inventory, Navy GSE be used?

YES NO N/A

COMMENTS

13. Is the point(s) at which the GSE interfaces with the subsystem accessible by the required number of maintenance personnel standing on the ground (deck) or standard work stands?

YES NO N/A

COMMENTS

14. Can the maintenance be performed with the aircraft's wings (tail surfaces) folded?

YES NO N/A

COMMENTS

15. Can the subsystem or component be exposed to precipitation or sea spray?

YES NO N/A

COMMENTS

16. Are a sufficient number of test points provided so that trouble-shooting can be performed without disassembly of units (5.9.15.2)?

YES NO N/A

COMMENTS

17. Are preflight and postflight inspections and troubleshooting facilitated by the design?

YES NO N/A

COMMENTS

18. Are mission or flight essential equipment accessible to the crew from the interior of the aircraft for emergency maintenance?

YES NO N/A

COMMENTS

<u>MOUNTING OF COMPONENTS WITHIN UNITS</u>

19. Are parts mounted in an orderly "two-dimensional" array (5.9.2.1)?

YES NO N/A

COMMENTS

20. Are components of similar form but different function mounted with a standard orientation throughout but readily distinguishable and not interchangeable (5.9.2.2)?

YES NO N/A

COMMENTS

21. Are delicate parts protected from damage during maintenance (5.9.2.3)?

YES NO N/A

COMMENTS

22. Are required lubrication points readily locatable, accessible and properly labeled (5.9.5)?

YES NO N/A

COMMENTS

ADJUSTMENT CONTROLS AND DISPLAYS

23. Are knobs used in preference to screwdriver adjustments for frequently used adjustment controls (5.9.3.1)?

YES NO N/A

COMMENTS

24. Do "blind" screwdriver adjustments have screwdriver shaft guides (5.9.3.2)?

YES NO N/A

COMMENTS

25. Are reference scales or displays used for adjustment feedback visible to the maintainer and located near the corresponding adjustment control (5.9.3.3)?

YES NO N/A

COMMENTS

26. Can the maintainer manipulate the control without obscuring the corresponding display with his hand or arm?

YES NO N/A

COMMENTS

27. Do display pointers move in the same direction as the corresponding control?

YES NO N/A

COMMENTS

28. Are all controls and displays arranged in order of operation?

YES NO N/A

COMMENTS

29. Are displays arranged in rows or columns?

YES NO N/A

COMMENTS

30. Are all nominal pointer settings identically aligned?

YES NO N/A

COMMENTS

31. Are frequently used displays and controls located in the most favorable positions?

YES NO N/A

COMMENTS

32. Are display formats as simple as possible and easily understood?

YES NO N/A

COMMENTS

33. Have MIL-STD-1472B control and display chapters been referenced in the design of maintenance consoles (5.1, 5.2, 5.3, 5.4, 5.5)?

YES NO N/A

COMMENTS

34. Are sensitive adjustments or controls protected from damage or inadvertant disturbance and is hand/arm support provided for the maintainer's use during adjustment tasks (5.9.3.4-5)?

YES NO N/A

COMMENTS

35. Are controls separated from or shielded from dangerous voltages, rotating machinery or any other personnel hazards (5.9.3.6)?

YES NO N/A

COMMENTS

36. Are such hazards properly labeled (5.9.3.6)?

YES NO N/A

COMMENTS

<u>ACCESSIBILITY</u>

37. Is access to or removal of components of units or chasis unobstructed by structural members (5.9.4.1)?

YES NO N/A

COMMENTS

38. Are large parts which are difficult to remove mounted so as not to prevent convenient access to other parts (5.9.4.2)?

YES NO N/A

COMMENTS

39. Are check points, adjustment controls, test points, cables, connectors, and labels accessible and visible to the maintainer using the proper test equipment or tools (5.9.4.3)?

YES NO N/A

COMMENTS

40. Does the equipment design facilitate access to the rear of units where required for maintenance (5.9.4.4)?

YES NO N/A

COMMENTS

41. Are units which are critical to system operation and require rapid maintenance most accessible (5.9.4.5)?

YES NO N/A

COMMENTS

42. Are high-failure-rate-items accessible without removing non-failed components (5.9.4.6)?

YES NO N/A

COMMENTS

43. Is access to units maintained by one type of technician possible without the removal of equipment maintained by another type technician (5.9.4.7)?

YES NO N/A

COMMENTS

CASES AND COVERS

44. Does the removal of any replaceable unit require opening or removing a minimum number of covers or panels (5.9.12.12)?

YES NO N/A

COMMENTS

45. Are holes through which screws must pass for mounting unit cases or covers large enough to preclude the necessity for perfect case alignment (5.9.6.1)?

YES NO N/A

COMMENTS

46. Are edges and corners of cases and covers rounded to prevent personnel injury (5.9.6.2)?

YES NO N/A

COMMENTS

47. Is the orientation of units within cases made obvious by case design or instructions (5.9.7.1)?

YES NO N/A

COMMENTS

48. Do cases lift off of units rather than units lifting out of cases (5.9.7.2)?

YES NO N/A

COMMENTS

49. Are cases large enough to prevent damage to units contained therein during case removal or replacement (5.9.7.3)?

YES NO N/A

COMMENTS

50. Are tracks, guides, and stops provided on cases to prevent damage or injury and to facilitate handling (5.9.7.4)?

YES NO N/A

COMMENTS

51. Is it obvious when covers (even when in place) are not secured (5.9.8.1)?

YES NO N/A

COMMENTS

52. If the method for opening covers is not obvious, are instructions permanently displayed on the covers (5.9.8.2)?

YES NO N/A

COMMENTS

53. If a unit requires frequent maintenance, is an access opening provided in lieu of removing a case or cover (5.9.9.1)?

YES NO N/A

COMMENTS

ACCESS OPENINGS AND COVERS

54. Are access covers self-supporting or completely removable (5.9.9.2)?

YES NO N/A

COMMENTS

55. Are access openings or covers properly labeled (5.9.9.3)?

YES NO N/A

COMMENTS

56. Are access openings large enough to allow the necessary parts of the maintainer's body and his tools within the unit in order to perform the required maintenance (5.9.9.4.1)?

YES NO N/A

COMMENTS

FASTENERS

57. Are fasteners standardized throughout the aircraft (5.9.10.1)?

YES NO N/A

COMMENTS

58. Are hand operated fasteners used where at all possible and fasteners requiring special tools not used (5.9.10.1)?

YES NO N/A

COMMENTS

59. Are hinges and tongue-and-slot catches used where possible to minimize the number of fasteners required (5.9.10.3)?

YES NO N/A

COMMENTS

60. Do hinged covers rotate 180° out of the maintainer's way?

YES NO N/A

COMMENTS

61. Are captive fasteners used (5.9.10.3)?

YES NO N/A

COMMENTS

62. Are the minimum number of fasteners (especially screws or bolts) used (5.9.10.4)?

YES NO N/A

COMMENTS

63. Can screws and bolts be removed with one common tool (5.9.10.7)?

YES NO N/A

COMMENTS

64. Are combination heads (slotted hex heads) used on bolts when feasible (5.9.10.7)?

YES NO N/A

COMMENTS

65. Are the number of turns required to release fasteners minimized (5.9.10.8)?

YES NO N/A

COMMENTS

66. Are mounting bolts and fasteners accessible (5.9.10.6)?

YES NO N/A

COMMENTS

UNIT HANDLING

67. Are irregular, fragile or awkward extensions easily removed from units before handling (5.9.11.2)?

YES NO N/A

COMMENTS

68. Are MIL-STD-1472B weight limits for the handling of units complied with (5.9.11.3)?

YES NO N/A

COMMENTS

69. Are proper handles or grasps provided for handling units (5.9.11.5)?

YES NO N/A

COMMENTS

MOUNTING

70. Are units removable along straight or slightly curved lines (5.9.12.3)?

YES NO N/A

COMMENTS

71. Are guide pins provided to facilitate mounting alignment (5.9.12.4)?

YES NO N/A

COMMENTS

72. Are replaceable items key coded to prevent insertion of a wrong item (5.9.12.5)?

YES NO N/A

COMMENTS

73. Do frequently removed units have rollout racks, slides, or hinges with safety stops (5.9.12.6-7)?

YES NO N/A

COMMENTS

74. Are interlocks provided to disconnect equipment that would be damaged by withdrawal of racks or drawers (5.9.12.8)?

YES NO N/A

COMMENTS

75. Are braces provided to support hinged units in the "out" position (5.9.12.9)?

YES NO N/A

COMMENTS

B. AIRFRAME

1. Are doors or access panels provided in the fuselage, airfoils, nacelles, control surfaces, etc. for inspecting, servicing, troubleshooting, and repairing all components contained within that are not accessible from the aircraft interior?

YES NO N/A

COMMENTS

2. Are all removable inspection doors labeled for expeditious reinstallation?

YES NO N/A

COMMENTS

3. Do all hinged doors open 180°?

YES NO N/A

COMMENTS

4. are piano type hinges used?

YES NO N/A

COMMENTS

5. Are hinges oriented so that the airstream tends to close the door?

YES NO N/A

COMMENTS

6. Are inspection doors located far enough from jet intakes so as not to be ingested if the door unfastens during engine operation?

YES NO N/A

COMMENTS

7. Are inspection door fasteners flush-type and quick opening?

YES NO N/A

COMMENTS

8. Do fasteners appear locked only when both the door and fastener are properly secured?

YES NO N/A

COMMENTS

9. Are access panels and inspection doors large enough to permit technicians wearing arctic gear (including gloves)?

YES NO N/A

COMMENTS

10. Does each fuel cell have a separate access door in the exterior of the aircraft?

YES NO N/A

COMMENTS

11. Are flight control components accessible for inspection and maintenance?

YES NO N/A

COMMENTS

12. Are bolts rather than rivets used for mounting assemblies that require removal for maintenance?

YES NO N/A

COMMENTS

13. Are airframe materials standard and uniform throughout the aircraft?

YES NO N/A

COMMENTS

14. Are airframe materials resistant to environmental factors (corrosion, dust, moisture, extreme temperatures, etc.)?

YES NO N/A

COMMENTS

15. Are airframe materials fire resistant?

YES NO N/A

COMMENTS

16. Are airframe materials easily fabricated, machined, and repaired?

YES NO N/A

COMMENTS

17. Do airframe repair materials not require heat treating before installation?

YES NO N/A

COMMENTS

18. Are hand grips, steps, and marked walkways provided where needed for the use of flight crews or maintenance personnel in the performance of their tasks?

YES NO N/A

COMMENTS

19. Are areas that cannot support personnel peoperly labeled "NO STEP"?

YES NO N/A

COMMENTS

20. Is ground handling and servicing of the airframe (towing, washing, lubrication, etc.) facilitated by the design?

YES NO N/A

COMMENTS

21. Are adjacent components which are subject to chafing (doors, control surfaces, etc.) designed so as to prevent the chafing?

YES NO N/A

COMMENTS

22. Are enclosed sections such as wings, control surfaces, non-pressurized tanks, etc. vented so as to ensure rapid pressure equalization during altitude changes?

YES NO N/A

COMMENTS

23. Are drain holes used in the skin and limber-holes in bulkheads and stiffeners to permit fluids to run to low points in the aircraft?

YES NO N/A

COMMENTS

24. Are drain holes located judiciously so that a minimum number is required and aerodynamic scavenging suction is produced in flight?

YES NO N/A

COMMENTS

25. Are jacking and hoisting points identified?

YES NO N/A

COMMENTS

<u>LANDING GEAR</u>

26. Are all units of landing gear accessible for lubrication, servicing, inspection, and replacement?

YES NO N/A

COMMENTS

27. Are hydraulic and pneumatic fittings (tire and strut shock absorber valves, bleed valves, etc.) accessible for servicing with the proper GSE?

YES NO N/A

COMMENTS

28. Are gear strut shock absorber adjustment parts accessible when the shock absorber is fully or partially inflated or deflated?

YES NO N/A

COMMENTS

29. Can shock absorber inflation be determined without the removal of any components or without the use of any measuring device other than a simple scale?

YES NO N/A

COMMENTS

30. Can wheels be removed without jacking the entire aircraft (preferrably only the affected mount should require jacking)?

YES NO N/A

COMMENTS

31. Are the brake assemblies so designed to provide ease of removal, repair, and replacement?

YES NO N/A

COMMENTS

32. Are brakes adjustable without the removal of any parts?

YES NO N/A

COMMENTS

33. Are inspection holes for examining the condition of brake pucks and disks provided?

YES NO N/A

COMMENTS

34. Are brake disks thick enough to allow several remachinings?

YES NO N/A

COMMENTS

35. Can brakes be rapidly serviced (filled, bled, and adjusted)?

YES NO N/A

COMMENTS

36. Are self-adjusting, self-bleeding brakes used if feasible and reliable?

YES NO N/A

COMMENTS

37. Can brakes be serviced using standard GSE?

YES NO N/A

COMMENTS

(AMCP 706-134)

C. ELECTRICAL/ELECTRONIC

1. Do all electrical and electronic components and installations comply with applicable military standards?

YES NO N/A

COMMENTS

2. Do acces doors to high voltage areas have provisions for automatically shutting off power when opened?

YES NO N/A

COMMENTS

CONDUCTORS

3. Are conductors properly bound into cables (5.9.13.1)?

YES NO N/A

COMMENTS

4. Are conductors and cables properly clamped to or ducted through the aircraft structure (5.9.13.3)?

YES NO N/A

COMMENTS

5. Are cables long enough to allow each unit to be checked conveniently and to facilitate connection and disconnection (5.9.13.4)?

YES NO N/A

COMMENTS

6. Are conductors color coded (5.9.13.2)?

YES NO N/A

COMMENTS

7. Are cables routed for accessibility for repair and inspection (5.9.13.6)?

YES NO N/A

COMMENTS

8. Are cables routed so as to prevent unnecessary wear and abuse (5.9.13.7)?

YES NO N/A

COMMENTS

9. Are cables that are exposed to wear or damage due to their passage through holes in partitions, protected by grommets (5.9.13.8)?

YES NO N/A

COMMENTS

10. Are cables labeled to indicate the equipment and connectors with which they are associated (5.9.13.9)?

YES NO N/A

COMMENTS

11. Are cables standardized for each installation of a given type of equipment?

YES NO N/A

COMMENTS

12. Can cable harnesses be factory built and installed as a unit?

YES NO N/A

COMMENTS

13. Are preformed cables used where possible?

YES NO N/A

COMMENTS

14. Are high temperature cables used especially near power plants?

YES NO N/A

COMMENTS

15. Is cable shielding secured to prevent shorting of exposed terminals?

YES NO N/A

COMMENTS

16. Are cables routed to avoid high temperature sources?

YES NO N/A

COMMENTS

17. Are cables protected from grease, oil, fuel, hydraulic fluid, water, etc.?

YES NO N/A

COMMENTS

18. Are cable ends protected from dust and moisture intrusion?

YES NO N/A

COMMENTS

(NAVORD OD 39223)

19. Is electrical wiring routed away from lines that carry flammable liquids?

YES NO N/A

COMMENTS

20. Are conduits designed to prevent collection of water and debris?

YES NO N/A

COMMENTS

21. Is direct routing of wiring through congested areas avoided?

YES NO N/A

COMMENTS

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CONNECTORS

22. Are quick-disconnect plugs used where feasible (5.9.14.1)?

YES NO N/A

COMMENTS

23. Are plugs keyed to prevent mismatching of connectors (5.9.14.2)?

YES NO N/A

COMMENTS

24. Are connecting plugs and receptacles readily identifiable (5.9.14.3)?

YES NO N/A

COMMENTS

25. Are alignment pins provided with plugs and receptacles to aid in rapid, corrcect insertion (5.9.14.4)?

YES NO N/A

COMMENTS

26. Are alignment pins longer than electrical pins (5.9.14.5)?

YES NO N/A

COMMENTS

27. Are all plugs and receptacles arranged so that aligning pins always have the same orientation throughout the aircraft (5.9.14.6)?

YES NO N/A

COMMENTS

28. Do plugs and receptacles have some form of visual coding in addition to aligning pins to aid in mating alignment (5.9.14.7)?

YES NO N/A

COMMENTS

29. Are adjustment connectors spaced far enough apart to allow a firm grasp for connection and disconnection (5.9.14.8)?

YES NO N/A

COMMENTS

30. Are the backs of plugs that do not require sealing accessible for testing and servicing (5.9.14.9)?

YES NO N/A

COMMENTS

31. Do replaceable electronic items have simple plug-in connectors (5.9.14.11)?

YES NO N/A

COMMENTS

32. Are connectors easily disassembled for pin replacement (5.9.14.12)?

YES NO N/A

COMMENTS

33. Are all pins on connectors identified?

YES NO N/A

COMMENTS

34. Are a few many-pin plugs used rather than many few-pin plugs?

YES NO N/A

COMMENTS

35. Are receptacles electrically "hot" and plugs electrically "cold"?

YES NO N/A

COMMENTS

36. Are connectors strong enough to withstand the expected use without damage?

YES NO N/A

COMMENTS

37. Are spare terminals provided on terminal strips and connectors?

YES NO N/A

COMMENTS

38. Are contacts large enough to carry the normal current plus a safety factor?

YES NO N/A

COMMENTS

39. Are terminal pins large enough to resist bending?

YES NO N/A

COMMENTS

40. Are protective covers provided for disconnected connectors?

YES NO N/A

COMMENTS

41. Are solder connections spaced far enough apart to allow work on individual connections without compromising the integrity of adjacent pins?

YES NO N/A

COMMENTS

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42. Do connectors have self-locking safety catches?

YES NO N/A

COMMENTS

43. Is the use of adapters avoided?

YES NO N/A

COMMENTS

44. Are connectors protected from shorting out due to foreign matter intrusion or contact with external objects?

YES NO N/A

COMMENTS

45. Are terminals marked + and - ?

YES NO N/A

COMMENTS

46. On removable units, will connectors disconnect before cables break?

YES NO N/A

COMMENTS

47. Are connectors used that do not require tools for disconnection?

YES NO N/A

COMMENTS

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TEST POINTS AND TEST EQUIPMENT

48. Are test points located near the corresponding controls and displays (5.9.15.1)?

YES NO N/A

COMMENTS

49. Is a sufficient number of test points provided so that subassemblies will not have to be removed from assemblies to accomplish trouble-shooting (5.9.15.2)?

YES NO N/A

COMMENTS

50. Is ample storage provided for in test equipment to contain all ancillary components required to operate the test equipment (5.9.16.1)?

YES NO N/A

COMMENTS

51. Are operating instructions for the test equipment visible to the operator during operation of the equipment (5.9.16.2)?

YES NO N/A

COMMENTS

52. Are test points placed at the input and output of each line replaceable unit?

YES NO N/A

COMMENTS

53. Are test points fully identified?

YES NO N/A

COMMENTS

54. Are all test points centrally located on a test panel for each unit?

YES NO N/A

COMMENTS

55. Are test points grouped for sequential testing?

YES NO N/A

COMMENTS

56. Are test points color coded for swift location and identification?

YES NO N/A

COMMENTS

57. Are test points labeled with the tolerance limits of the signal?

YES NO N/A

COMMENTS

58. Are routine test points located so that they can be used without removal of cabinet covers or chasis?

YES NO N/A

COMMENTS

59. Can voltage dividers be used to lower the potential of high voltage test points?

YES NO N/A

COMMENTS

60. Is the test equipment simple to operate?

YES NO N/A

COMMENTS

61. Is the test equipment self-checking and calibrating?

YES NO N/A

COMMENTS

62. Is the calibration test a simple go/no go indication?

YES NO N/A

COMMENTS

63. Are selector switches used on test equipment instead of many plug-in connections?

YES NO N/A

COMMENTS

64. Are test equipment controls, displays and connectors standardized?

YES NO N/A

COMMENTS

65. Does the test equipment test components in order of increasing reliability?

YES NO N/A

COMMENTS

66. Is the test equipment designed to minimize operator errors and operation time?

YES NO N/A

COMMENTS

67. Are the number of tests minimized?

YES NO N/A

COMMENTS

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<u>FAILURE INDICATION AND CIRCUIT PROTECTION</u>

68. When required, are indicators provided that reveal fuse or circuit breaker opening (5.9.17.2.1)?

YES NO N/A

COMMENTS

69. Is an indication of electrical power failure provided (5.9.17.1.1)?

YES NO N/A

COMMENTS

70. Are displays provided to indicate when equipment has failed or is not operating within tolerance limits (5.9.17.1.2)?

YES NO N/A

COMMENTS

71. Are auditory alarms provided to indicate critical malfunctions of equipment that is not regularly monitored (5.9.17.1.3)?

YES NO N/A

COMMENTS

72. Are fuse and circuit breaker panels labeled with amperages and equipment serviced (5.9.17.2.1)?

YES NO N/A

COMMENTS

73. Are fuse and circuit breaker panels readily accessible for replacement or resetting of open circuit protectors (5.9.17.2.2)?

YES NO N/A

COMMENTS

74. Are spare fuse holders available near the fuse panel (5.9.17.2.2)?

YES NO N/A

COMMENTS

75. Can fuses be replaced and circuit breakers reset without the use of tools (5.9.17.2.2)?

YES NO N/A

COMMENTS

76. Is each unit of the subsystem separately protected by fuse or circuit breakers?

YES NO N/A

COMMENTS

BATTERIES

77. Are batteries located away from sources of heat?

YES NO N/A

COMMENTS

78. Will batteries function under all ambient operational temperature ranges?

YES NO N/A

COMMENTS

79. Are battery holders strong enough to hold the battery firmly under all G-loads?

YES NO N/A

COMMENTS

80. Do battery clamping devices operate easily without the use of tools for removal?

YES NO N/A

COMMENTS

81. Are batteries readily accessible for removal by one technician from ground level?

YES NO N/A

COMMENTS

82. Can batteries be serviced while installed?

YES NO N/A

COMMENTS

83. Are safety caps provided to protect battery terminals and personnel during removal and handling?

YES NO N/A

COMMENTS

84. Are battery housings well drained and ventilated?

YES NO N/A

COMMENTS

85. Are battery housings painted with acid proof paint?

YES NO N/A

COMMENTS

86. Are non-sparking electrical fixtures used in the battery compartments?

YES NO N/A

COMMENTS

87. Do battery leads have quick-disconnects?

YES NO N/A

COMMENTS

88. Are batteries and battery compartments properly labeled?

YES NO N/A

COMMENTS

89. Are "dry" batteries installed in housings that protect them from water and other contaminants?

YES NO N/A

COMMENTS

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RELAYS

90. Are relay contacts as large as possible and made of arc-resistant material?

YES NO N/A

COMMENTS

91. Are hermetically sealed, vacuum or inert gas filled relays used to avoid oxidation or corrosion of contacts?

YES NO N/A

COMMENTS

92. Are synthetic insulating materials used in the construction of relays?

YES NO N/A

COMMENTS

93. To avcid power surges, are decoupling networks and filters used in conjunction with relays which control large currents?

YES NO N/A

COMMENTS

94. Are relays designed to decrease the effects of physical shock and vibration accompanying contact closing?

YES NO N/A

COMMENTS

95. Do circuits requiring relays have a positive feedback loop to ensure proper relay operation?

YES NO N/A

COMMENTS

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D. POWER PLANTS

1. Are engine installation features designed for quick engine change?

   YES NO N/A

   COMMENTS

2. Are quick-disconnect features employed?

   YES NO N/A

   COMMENTS

3. Are similar parts having the same function interchangeable?

   YES NO N/A

   COMMENTS

4. Are power plant installations of multi-engine aircraft identical for all engine stations, permitting complete interchangeability?

   YES NO N/A

   COMMENTS

5. Are hoisting lugs and handling points provided on units such as engines, gear boxes and other similar units which exceed 45 lbs.?

   YES NO N/A

   COMMENTS

6. Do detachable engine accessory units fit any power plant on the aircraft with minimum adaptation?

YES NO N/A

COMMENTS

7. Are large, quick-opening access doors and sufficient space provided for maintaining, servicing, and inspecting engines and their accessory sections?

YES NO N/A

COMMENTS

8. Is split-line design used for maximum accessibility to engine components, such as split compressor and cumbustion chamber housings?

YES NO N/A

COMMENTS

9. Are major engine components such as compressors, turbines, combustion chambers, etc. designed as complete assemblies to be removable and replaceable as units?

YES NO N/A

COMMENTS

10. Are engine mounting brackets part of the main chasis to facilitate engine removal?

YES NO N/A

COMMENTS

11. Are self-aligning mounting bolts used to install engines?

YES NO N/A

COMMENTS

12. Are accessory gear drives and their related accessories mounted at the most generally accessible positions of the engine?

YES NO N/A

COMMENTS

13. Are engine accessories mounted so that they are accessible for inspection, servicing, and removal without removal of the engine or other power plant structures?

YES NO N/A

COMMENTS

14. Is the power plant installation designed so that daily, preflight, and postflight inspections can be made by personnel wearing cold weather clothing?

YES NO N/A

COMMENTS

15. Are fluid drains accessible for inspection?

YES NO N/A

COMMENTS

16. Are adequate provisions incorporated in the engine cooling system for rapid inspection, repair, and replacement of the tailpipe, flexible coupling, and all other related components?

YES NO N/A

COMMENTS

17. Is the turbine housing removable for visual inspection of rotor blades?

YES NO N/A

COMMENTS

18. Can turbine rotor and stator blades be removed and reinstalled by hand?

YES NO N/A

COMMENTS

19. Are bearings accessible for inspection, lubrication, and replacement?

YES NO N/A

COMMENTS

20. Are split bearings used to facilitate bearing removal?

YES NO N/A

COMMENTS

21. Are bearings used in tandem pairs so that removal of one for servicing, repair, etc. allows the second to support the component?

YES NO N/A

COMMENTS

22. Are bearing seals made of highest quality material to ensure the longest possible service?

YES NO N/A

COMMENTS

23. Are bearing seal housings designed for ease of replacement of the seals?

YES NO N/A

COMMENTS

24. Are power plants designed to prevent erroneous component installation ("Murphy")?

YES NO N/A

COMMENTS

25. Are maintenance personnel shielded from mechanical hazards or high temperatures while performing maintenance on engines?

YES NO N/A

COMMENTS

26. Are subsystems which transmit combustible gases or liquids to, from, or in the vicinity of engines designed to minimize fire hazard in accordance with applicable standards and specifications?

YES NO N/A

COMMENTS

27. Is military standard or specified fire extinguishing equipment included in the power plant design?

YES NO N/A

COMMENTS

28. Are power plants designed to resist or withstand fire?

YES NO N/A

COMMENTS

29. Are engine sections vented to remove explosive fuel air mixtures?

YES NO N/A

COMMENTS

30. Are power plant sections properly drained of combustible fluids?

YES NO N/A

COMMENTS

31. Are engine air intakes and exhaust gas outlets designed to minimize hazards to personnel in their vicinity?

YES NO N/A

COMMENTS

32. In turboprop aircraft, are propeller assemblies designed for quick removal and installation from engines so as not to delay engine changing?

YES NO N/A

COMMENTS

33. Are clutches designed with split-line elements so that clutch components can be rapidly removed and replaced without engine or gear box removal?

YES NO N/A

COMMENTS

34. Are dry clutches designed so as to prevent oil leakage on the clutch elements?

YES NO N/A

COMMENTS

35. Are thrust bearings removable and replaceable without removing other equipment (preferrably split type bearings should be used)?

YES NO N/A

COMMENTS

36. Are magnetic chip detectors provided in all engines and gear boxes with corresponding warning lights?

YES NO N/A

COMMENTS

37. Are highest quality spark plugs or igniters used and are they easily accessible?

YES NO N/A

COMMENTS

38. Are engine oil, fuel, and ignition control components accessible for servicing and adjustment?

YES NO N/A

COMMENTS

39. Are engine monitoring instruments and devices easily accessible for servicing, calibration, and replacement?

YES NO N/A

COMMENTS

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E. HYDRAULICS, FUEL AND OTHER FLUIDS

1. Can the fluid subsystems be serviced and inspected quickly from ground level using standard GSE (fuel trucks, oilers, hydraulic servicing units)?

YES NO N/A

COMMENTS

2. Are quick-release hose and pipe fittings and connectors used?

YES NO N/A

COMMENTS

3. Are hoses, pipes, fittings, and connectors color coded and labeled in accordance with MIL-STD-1247?

YES NO N/A

COMMENTS

4. Are connectors and fittings designed so that they cannot be improperly installed?

YES NO N/A

COMMENTS

5. Are flammable liquid subsystems designed according to directives for minimum vulnerability to fire due to operation or enemy action?

YES NO N/A

COMMENTS

6. Are shut-off valves and compartmentation used to isolate combustible liquids from heat sources?

YES NO N/A

COMMENTS

7. Are tanks well vented for both pressure equalization and fire prevention?

YES NO N/A

COMMENTS

8. Are all major hydraulic components located in one accessible area?

YES NO N/A

COMMENTS

9. Is the hydraulic reservoir visually accessible for refilling so as not to overfill the system?

YES NO N/A

COMMENTS

10. Are tank and reservoir drain valves located for removal from outside the tank or reservoir?

YES NO N/A

COMMENTS

11. Are tanks and reservoirs placed at the high points of the subsystem?

YES NO N/A

COMMENTS

12. Are tanks self-sealing?

YES NO N/A

COMMENTS

13. Do all tanks have access doors large enough to allow inspection, cleaning, and maintenance of the entire tank interior?

YES NO N/A

COMMENTS

14. Are tanks easily removable?

YES NO N/A

COMMENTS

15. Are tanks removable without first removing the engine or any of its components?

YES NO N/A

COMMENTS

16. Are tanks designed so as not to be structurally part of the aircraft (bladder liners of structural cavities are encouraged)?

YES NO N/A

COMMENTS

17. Are tank and reservoir support fittings and fasteners designed so as not to pass through the liquid barrier?

YES NO N/A

COMMENTS

18. Are pumps, filters, valves, and other equipment mounted within tanks readily removable without removing the tank from the aircraft?

YES NO N/A

COMMENTS

19. Are pumps easily and rapidly removable and replaceable?

YES NO N/A

COMMENTS

20. Are valves designed to permit rapid and easy replacement of all internal seats, seals and packings without removal of the valve from the system or the piping from the valve?

YES NO N/A

COMMENTS

21. Is clearance provided for removal of sumps or inspection doors and plates?

YES NO N/A

COMMENTS

22. Are fuel tank compartments sealed and dammed from other portions of the aircraft?

YES NO N/A

COMMENTS

23. Do all drain and vent lines terminate outside of the aircraft?

YES NO N/A

COMMENTS

24. Are drain lines accessible for drainage from outside the aircraft?

YES NO N/A

COMMENTS

25. Are drain lines from hydraulic, fuel, oil, water-alcohol, etc. components separate from drain lines from electrical accessories?

YES NO N/A

COMMENTS

26. Are fluid subsystem filler caps designed so that they cannot be improperly secured?

YES NO N/A

COMMENTS

27. Do filters trap water as well as solid contaminants?

YES NO N/A

COMMENTS

28. Are filter drain lines flexible so that they do not have to de disconnected when removing filters from filter housings?

YES NO N/A

COMMENTS

29. Are fuel lines designed with constant vertical displacement to avoid sumps in the lines which may collect water that may freeze or otherwise starve the engine fcr fuel?

YES NO N/A

COMMENTS

30. Are a sufficient number of fittings, with plugs or valves, provided for attaching pressure or temperature calibrating test equipment?

YES NO N/A

COMMENTS

31. Are accessible bleeds provided to remove trapped air?

YES NO N/A

COMMENTS

32. Are hydraulic actuating cylinders and liners easily replaceable?

YES NO N/A

COMMENTS

33. Are actuating cylinders accessible for rapid, easy removal and replacement?

YES NO N/A

COMMENTS

34. Are valve installations designed to prevent outside contaminants from entering vent port openings?

YES NO N/A

COMMENTS

35. Are lines routed so that normal piping and emergency piping of compatible subsystems are physically separated thus avoiding the possibility of simultaneous casualty to the subsystem and its backup?

YES NO N/A

COMMENTS

36. When groups of pipes are attached side-by-side, is there sufficient clearance so that individual pipes may be replaced without removing the adjacent piping?

YES NO N/A

COMMENTS

37. Are pipes rigidly supported at possible chafing points?

YES NO N/A

COMMENTS

38. Are fittings at charging points for accumulators, gas cylinders, etc. accessible and externally located if possible?

YES NO N/A

COMMENTS

39. Are pressure relief valves provided to relieve excessive system or thermal pressure?

YES NO N/A

COMMENTS

40. Do direct reading pressure gages have safety blowout plugs or disks that will relieve excessive pressure before the gage fails and possibly injures personnel?

YES NO N/A

COMMENTS

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41. Are seals visible externally when installed?

YES NO N/A

COMMENTS

42. Do gaskets and seals not protrude or extrude beyond the coupling?

YES NO N/A

COMMENTS

43. Are seals replaceable?

YES NO N/A

COMMENTS

44. Are safety fittings with builtin check valves used?

YES NO N/A

COMMENTS

45. Is the hydraulic subsystem automatically bleeding wherever possible?

YES NO N/A

COMMENTS

46. Is standard mounting hardware used?

YES NO N/A

COMMENTS

47. Are fittings and connectors standardized and the number of different sizes minimized?

YES NO N/A

COMMENTS

48. Are connectors designed so that it is physically impossible to mismate different connectors?

YES NO N/A

COMMENTS

49. Can trapped pressure be safely relieved before opening connectors for maintenance?

YES NO N/A

COMMENTS

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F. WEAPONS

1. Can ordnance be loaded on weapon stations or components from ground level by personnel using standard loading equipment?

   YES NO N/A

   COMMENTS

2. Are internally carried weapons subsystem components easily accessible through large doors for loading, servicing, or maintenance?

   YES NO N/A

   COMMENTS

3. Are cannon, missile rails and bomb stations located so that a minimum amount or no lifting of heavy ordnance is required by loading personnel?

   YES NO N/A

   COMMENTS

4. Can all weapons stations be properly loaded with the aircraft's wings folded?

   YES NO N/A

   COMMENTS

5. Can all weapons stations be loaded when part of the aircraft (especially the aft portion) overhangs the deck edge?

   YES NO N/A

   COMMENTS

6. Can all weapons stations be loaded when the landing gear are down and the landing gear doors are in the open position?

YES NO N/A

COMMENTS

7. Are electrical, hydraulic, or pneumatic connectors associated with various weapons easily accessible for loading or maintenance?

YES NO N/A

COMMENTS

8. Can all ordnance stations that require arming by ground personnel while the engines are operating be armed without exposing the ground personnel to air intakes, exhaust nozzles, dangerous electromagnetic radiation, operating mechanical equipment, moving control surfaces, or other hazards?

YES NO N/A

COMMENTS

9. Can ground personnel arm ordnance by hand without opening any access doors or panels?

YES NO N/A

COMMENTS

10. Are all weapons components easily accessible and easily removed and replaced for maintenance that cannot be performed onboard the aircraft?

YES NO N/A

COMMENTS

G. CREW SUBSYSTEMS

1. Are cockpit and crew station display and control panels easily removable?

   YES NO N/A

   COMMENTS

2. Are individual displays or controls easily accessible and removable from panels?

   YES NO N/A

   COMMENTS

3. Can maintenance be performed on display and control panels without their removal while retaining basic accessibility characteristics?

   YES NO N/A

   COMMENTS

4. Are connectors for displays and controls quickly disconnectable?

   YES NO N/A

   COMMENTS

5. Is it physically impossible to mismate or otherwise improperly install control and display devices?

   YES NO N/A

   COMMENTS

6. Are flight control devices (stick and rudder pedals, etc.) and their corresponding electronics, hydraulics, and mechanics designed to facilitate inspection, adjustment, repair, and replacement?

YES NO N/A

COMMENTS

7. Are controls that may otherwise be inadvertantly actuated by maintenance personnel and result in a casualty located, labeled, and if possible failsafed to avoid such accidents (these hazards include ejection seat, canopy jettison, landing gear, flaps and engine starting controls)?

YES NO N/A

COMMENTS

8. Can cockpit or crew station components which may necessarily (due to human factors engineering for the operator) obstruct removal of other components be easily removed and replaced?

YES NO N/A

COMMENTS

9. Especially on larger, multi-engine aircraft, can inflight maintenance be performed easily by the operator with a limited number of tools?

YES NO - N/A

COMMENTS

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